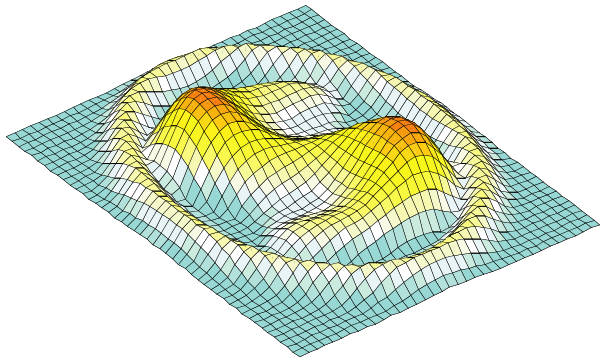
Surface Operation Automation Research
— SOAR —

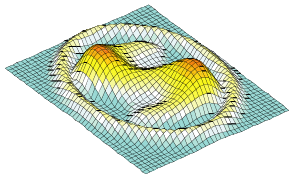
Dr. Victor H. L. Cheng
Optimal Synthesis Inc.
Los Altos, California

Virtual Airspace Modeling and Simulation (VAMS)
Air Transportation System Capacity-Increasing Research
Technical Interchange Meeting
January 14–15, 2003

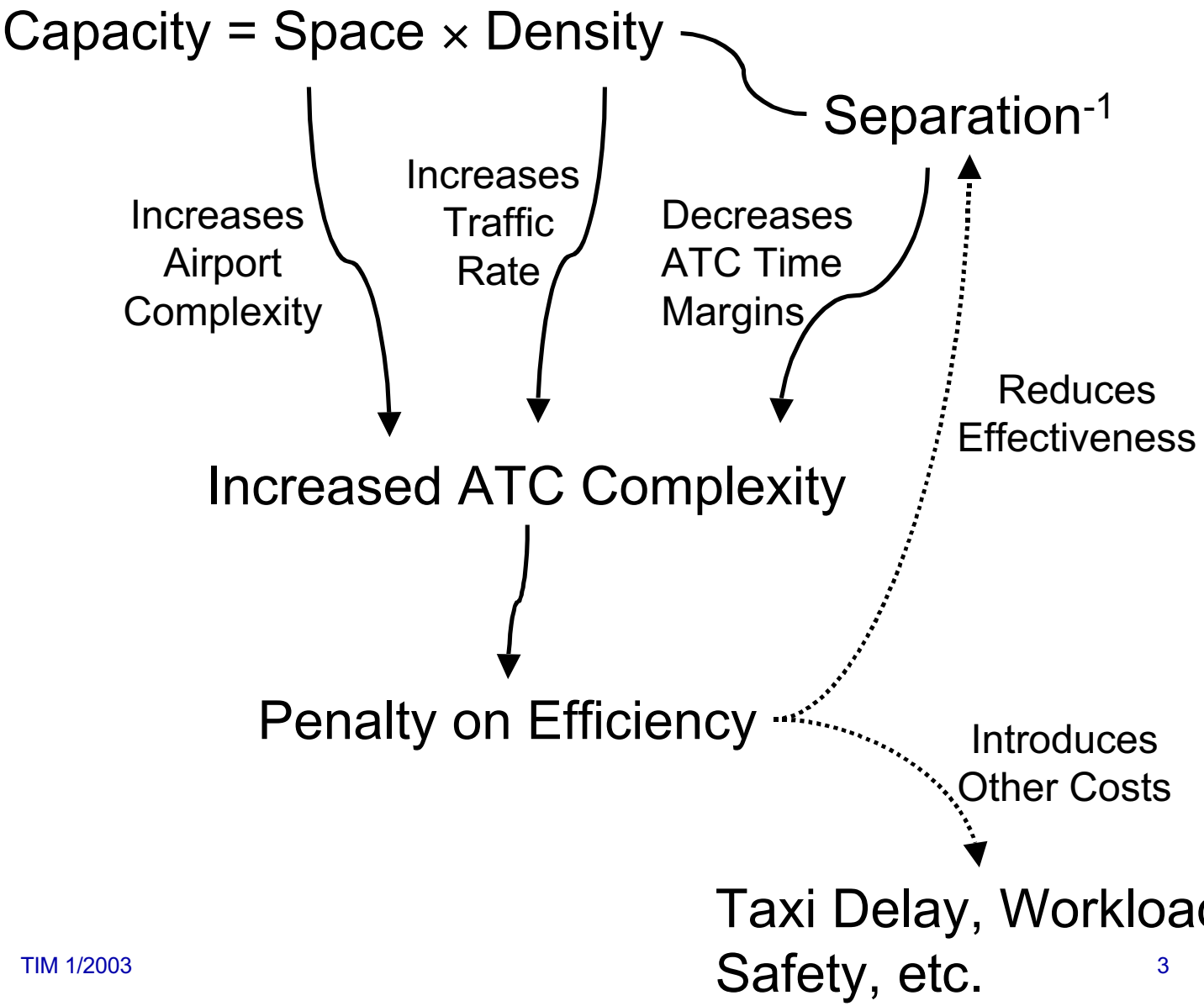


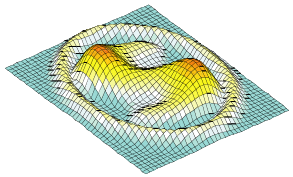
Outline

- Airport Capacity Enhancement Issues
- SOAR Concept
- ATM Automation Functions
- Flight-Deck Automation Functions
- Integrated Operation of SOAR Systems
- System Performance
- Human Performance
- Concept Development and Technology Roadmap



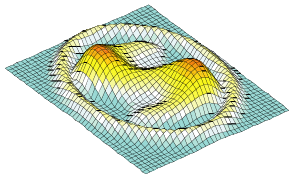
Airport Capacity Enhancement Issues



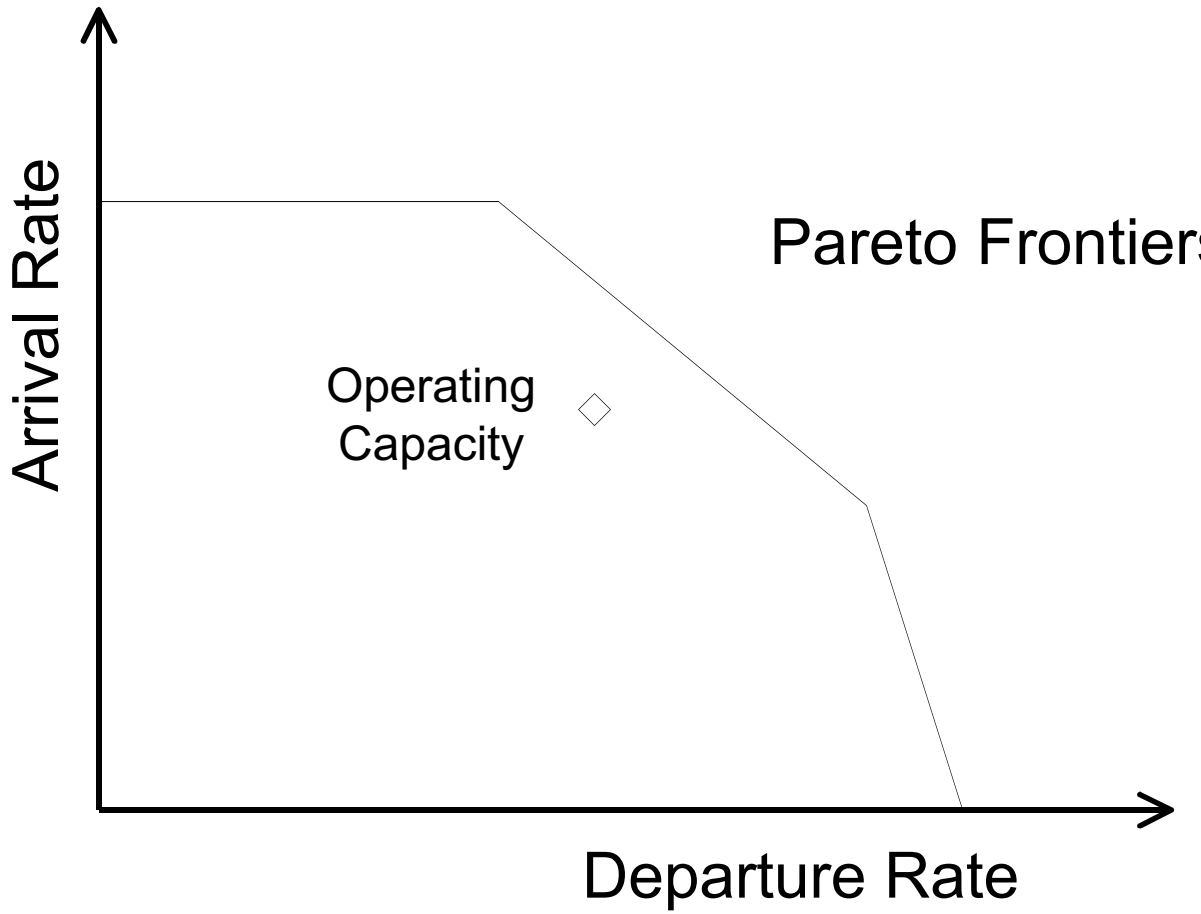


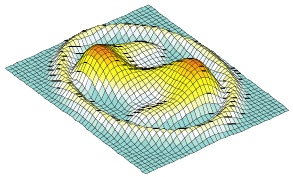
Quantitative Goals

- **Bi-objective airport capacity problem: Pareto frontiers describe balance between departure and arrival traffics.**
- **Achievable airport capacity can be maximized by lowering priorities of other surface traffic: undesirable taxi delays.**
- **SOAR concept seeks enhancement with tradeoff between two efficiency factors:**
  - **Reduction in achievable traffic rate, a penalty on arrival/departure efficiency**
  - **Increase in taxi delay, a penalty on surface traffic efficiency**
- **Quantitative goals: enhance and strike balance between these efficiency factors, e.g. simultaneously**
  - **achieve 90% of the ideal airport capacity**
  - **maintain cumulative delay to within 10% of the cumulative ideal taxi time**



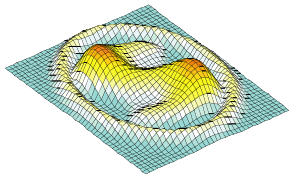
Bi-objective Capacity Optimization



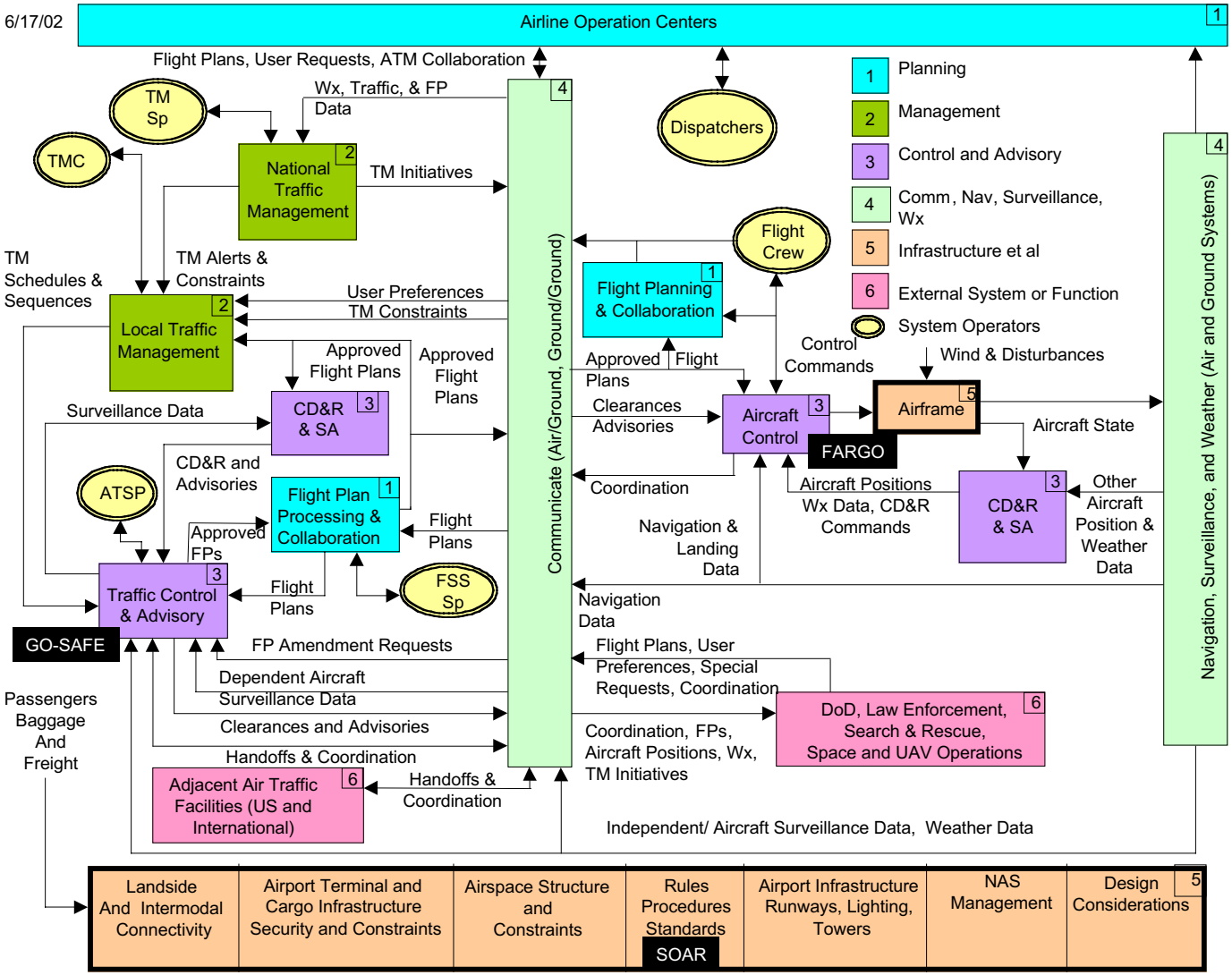


SOAR Concept

- Advanced automation in Centralized Decision-making, Distributed Control (CDDC) paradigm
- Centralized Decision-Making: Ground-Operation Situation Awareness and Flow Efficiency (GO-SAFE) for Surface Traffic Management (STM) Automation
  - Basic functions studied under previous SBIR Phase II effort
- Distributed Control: Flight-deck Automation for Reliable Ground Operation (FARGO) for Flight Deck Automation
  - Feasibility of high-precision taxi control demonstrated in previous SBIR Phase I study
- Integrated operation of both systems
  - GO-SAFE to help issue efficient time-based taxi clearances
  - FARGO to help execute taxi clearances

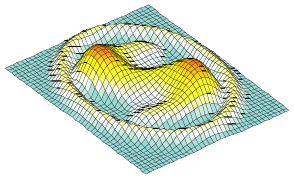


GFI Model with SOAR Technology Components

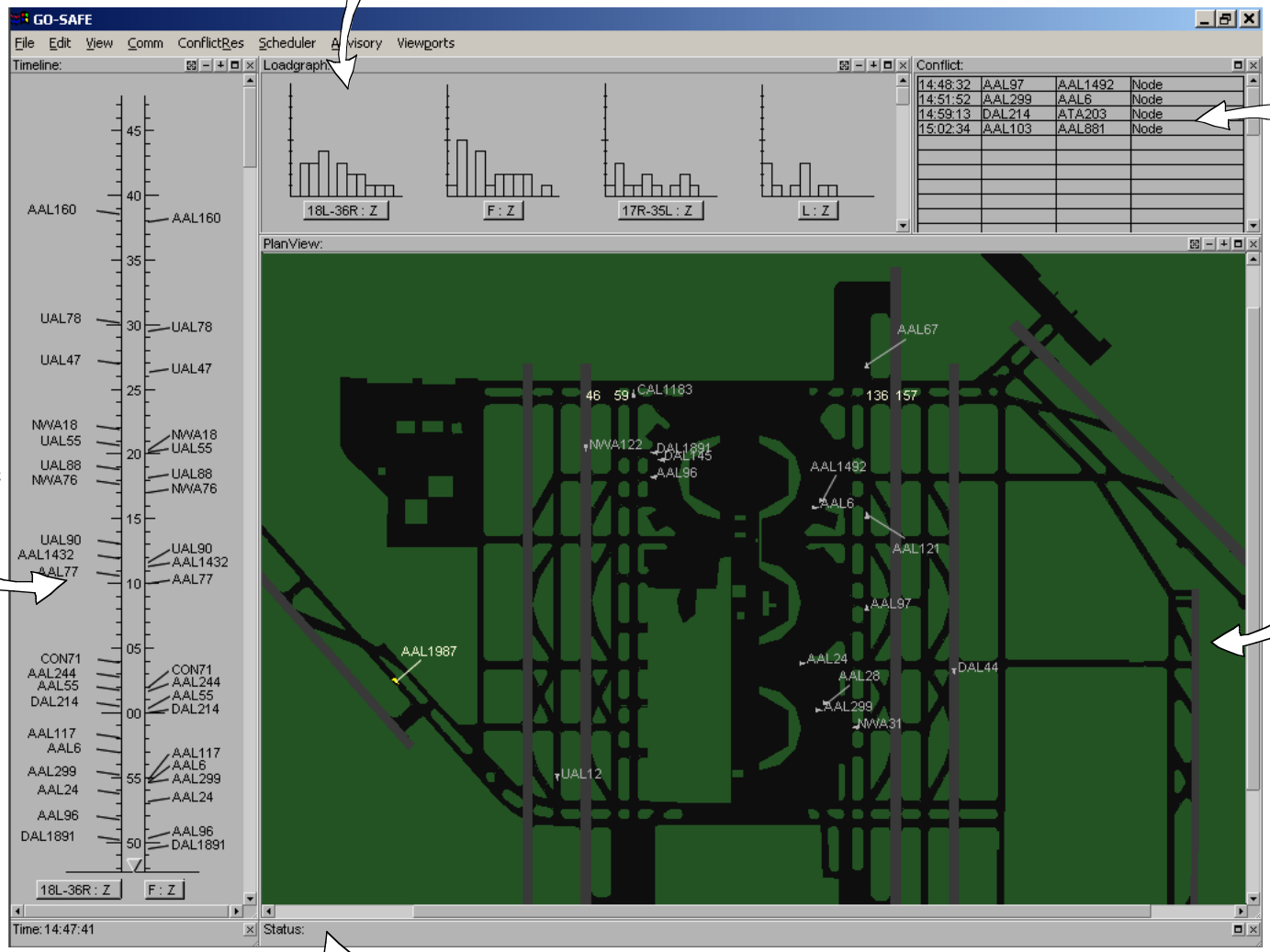


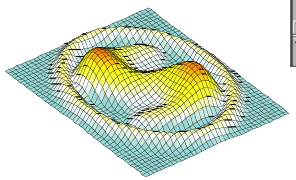
STM Automation Functions

- User interface, including situational display for monitoring surface traffic, and alerting of impending problems
  - Updated to allow easy reconfiguration to support Phase II evaluations
- Taxi-route generation and editing
  - Previous taxi-route generation based on dynamic programming for route optimization
  - GO-SAFE software architecture allows inclusion of multiple route-generation techniques
  - Route editing functions enabled by GUI: end-point change, route change, timing change
- Conflict detection and resolution
- Decision support tool for efficient and safe operation

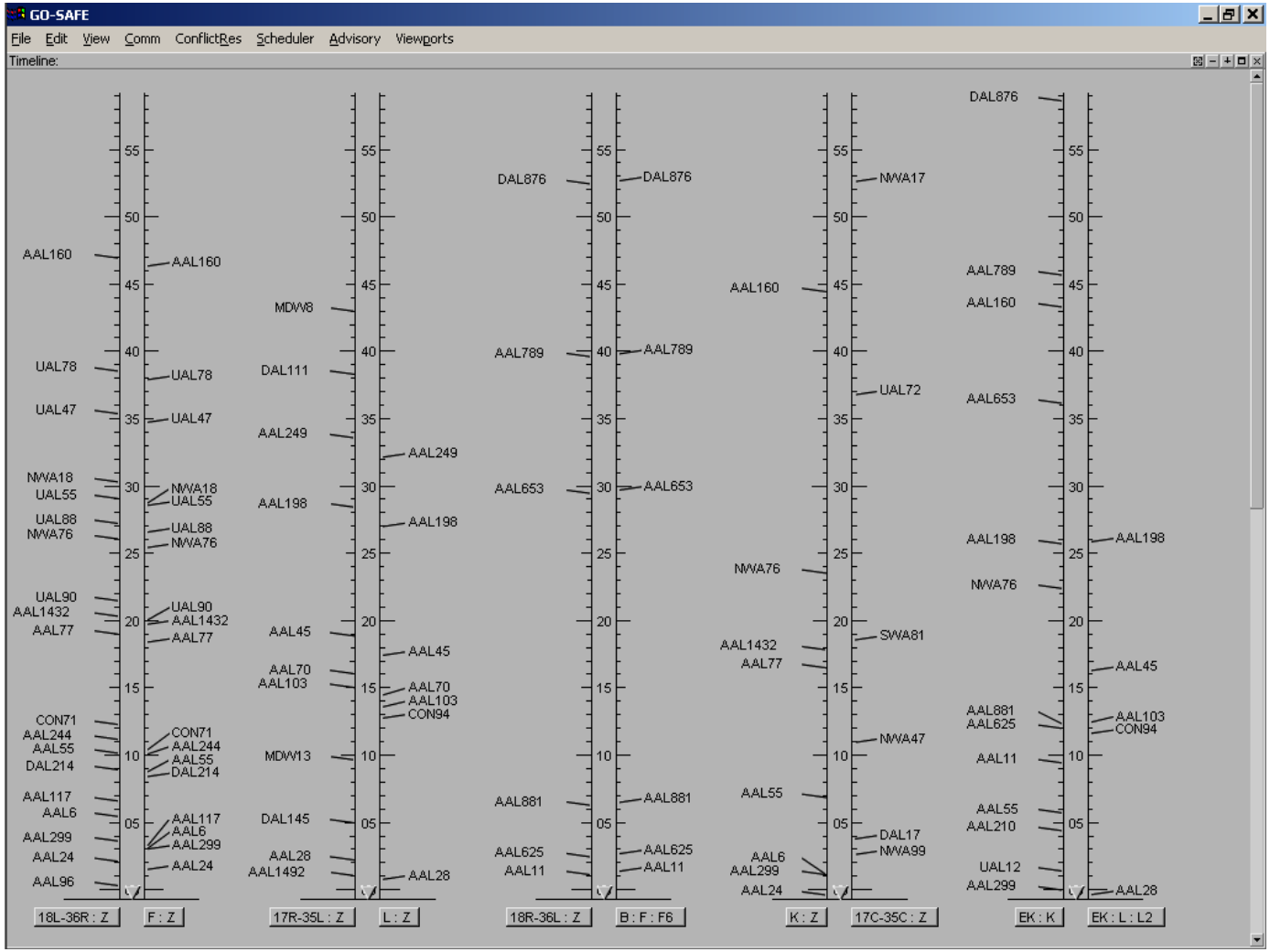


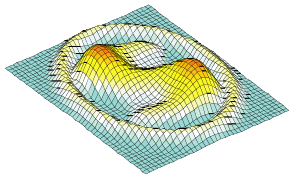
Overview of GO-SAFE GUI



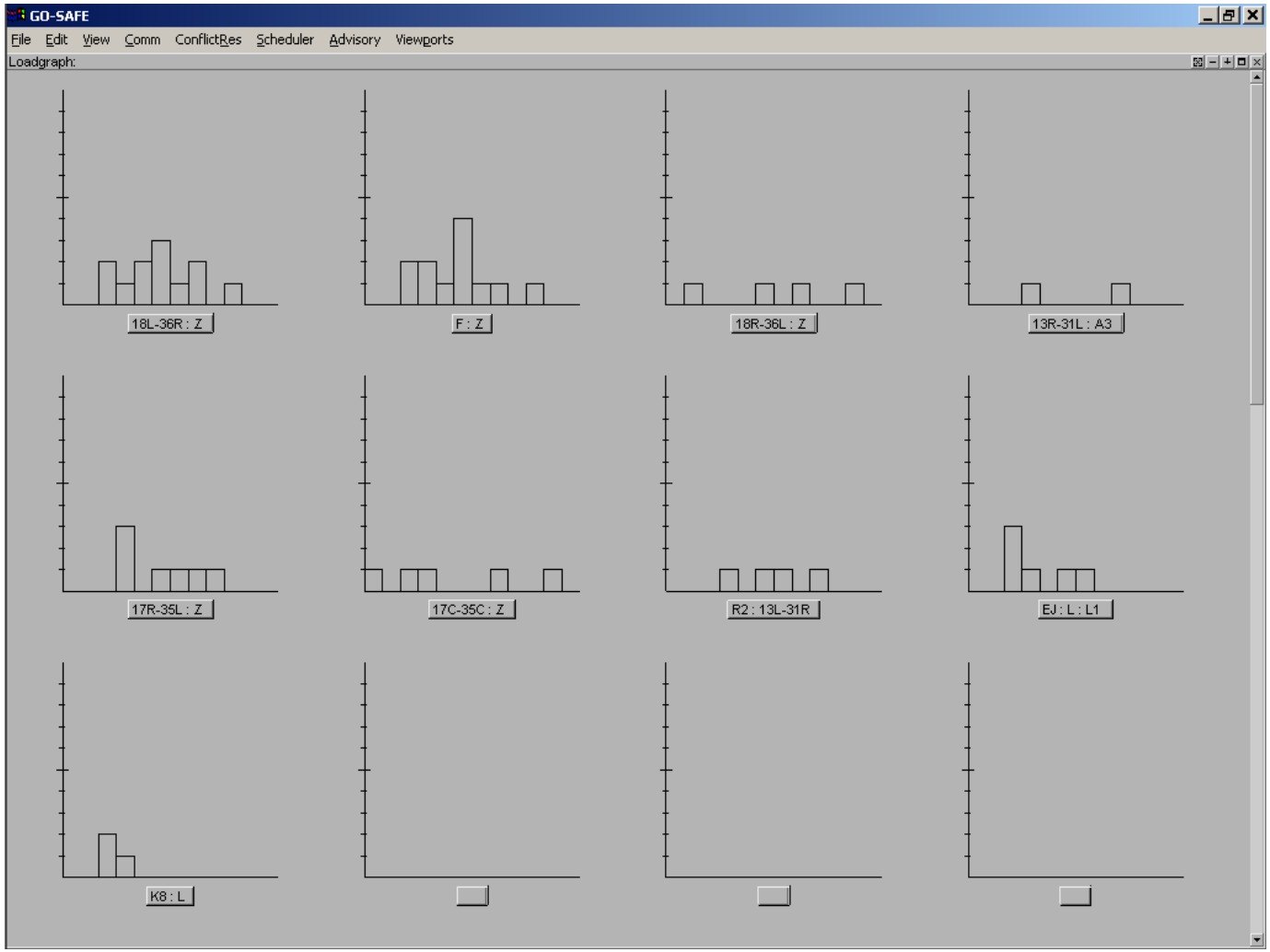


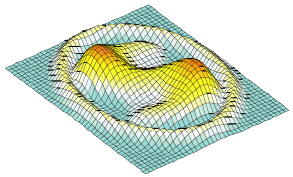
Sample Full-Screen Time-Line Display





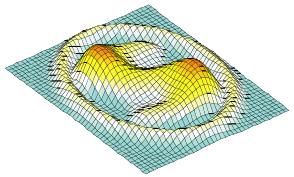
Sample Full-Screen Load-Graph Display





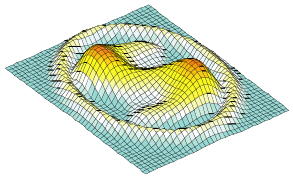
Conflict Detection and Resolution

- Requirements for conflicts on airport surface not as serious as for IFR flights: in current operations, cockpit crew is responsible for separation while taxiing.
- Conflicts of taxi routes in internal representations of GO-SAFE can be resolved
  - Manually by controller through route editing
  - Automatically by GO-SAFE with timing changes
- All time-based taxi routes must be conflict-free.
- Clearances composed of conflict-free routes will facilitate detection of real-world conflicts
  - Any conflicts caused by flights with cleared routes must mean the flights have deviated from the routes.

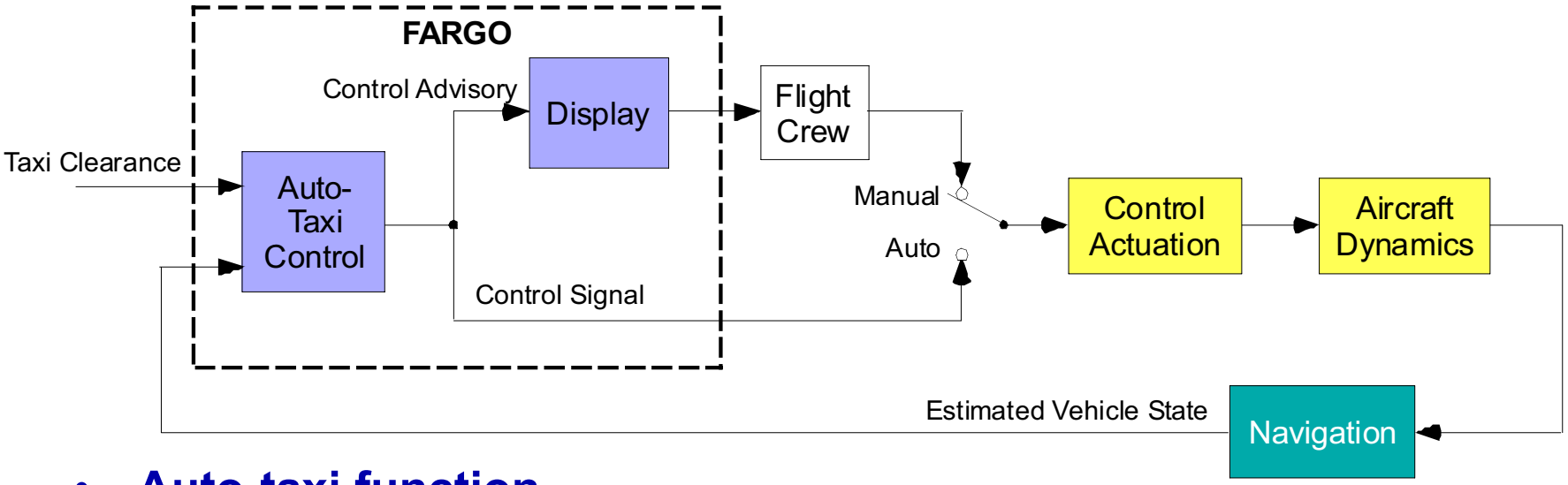


Decision Support System

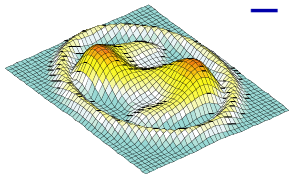
- **Surface Resource Scheduler**
  - **Runway usage for landing, takeoff and crossing traffic**
  - **Other surface resources: special facilities (e.g. de-icing), identified choke points**
- **Clearance Manager**
  - **Manages and issues advisories/clearances**
  - **Encodes clearances according to route definition, including crossing time restrictions**
  - **Monitors clearances and flight clearance status**
  - **Assists with route changes: "what-if" capability to predict impact of modified routes**
- **Conformance Monitor**
  - **Monitors aircraft compliance with clearances**
  - **Detect incursions and conflicts with other flights or ground vehicles**



Flight-Deck Automation Functions

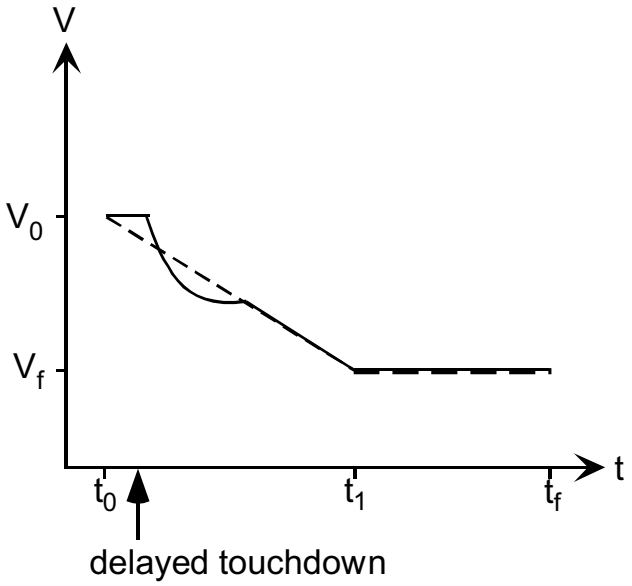


- **Auto-taxi function**
  - **Precise control of aircraft taxi to execute clearance**
  - **Potential use of time-based taxi routes, decoded from clearance**
  - **Guidance signal for driving pilot interface**
- **Pilot interface to allow the pilots to perform precision-taxi**
  - **Far-term: fully automatic taxi**
  - **Near-term: control signals generated by the auto-taxi function to direct manual control**

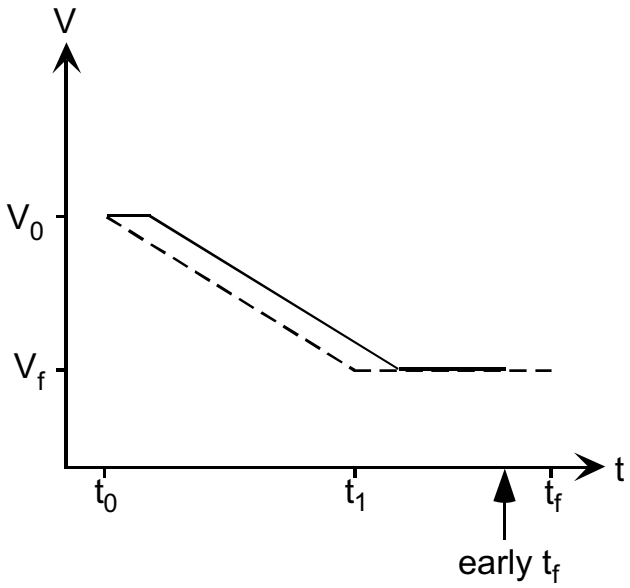


Auto-Taxi Control

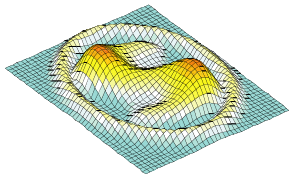
- **Nominal guidance assures passenger comfort and safety.**
- **Must be robust in off-nominal situations: e.g. prolonged flare during landing.**



- Excessive deceleration

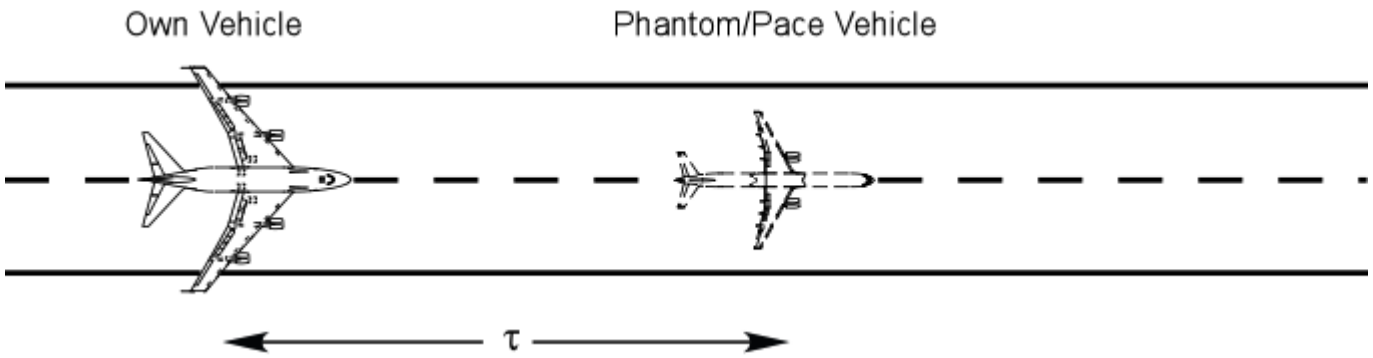


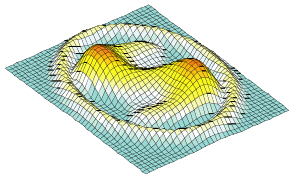
- Speed too high at turnoff
- Arrival too early at scheduled intersection



Pilot Interface Considerations

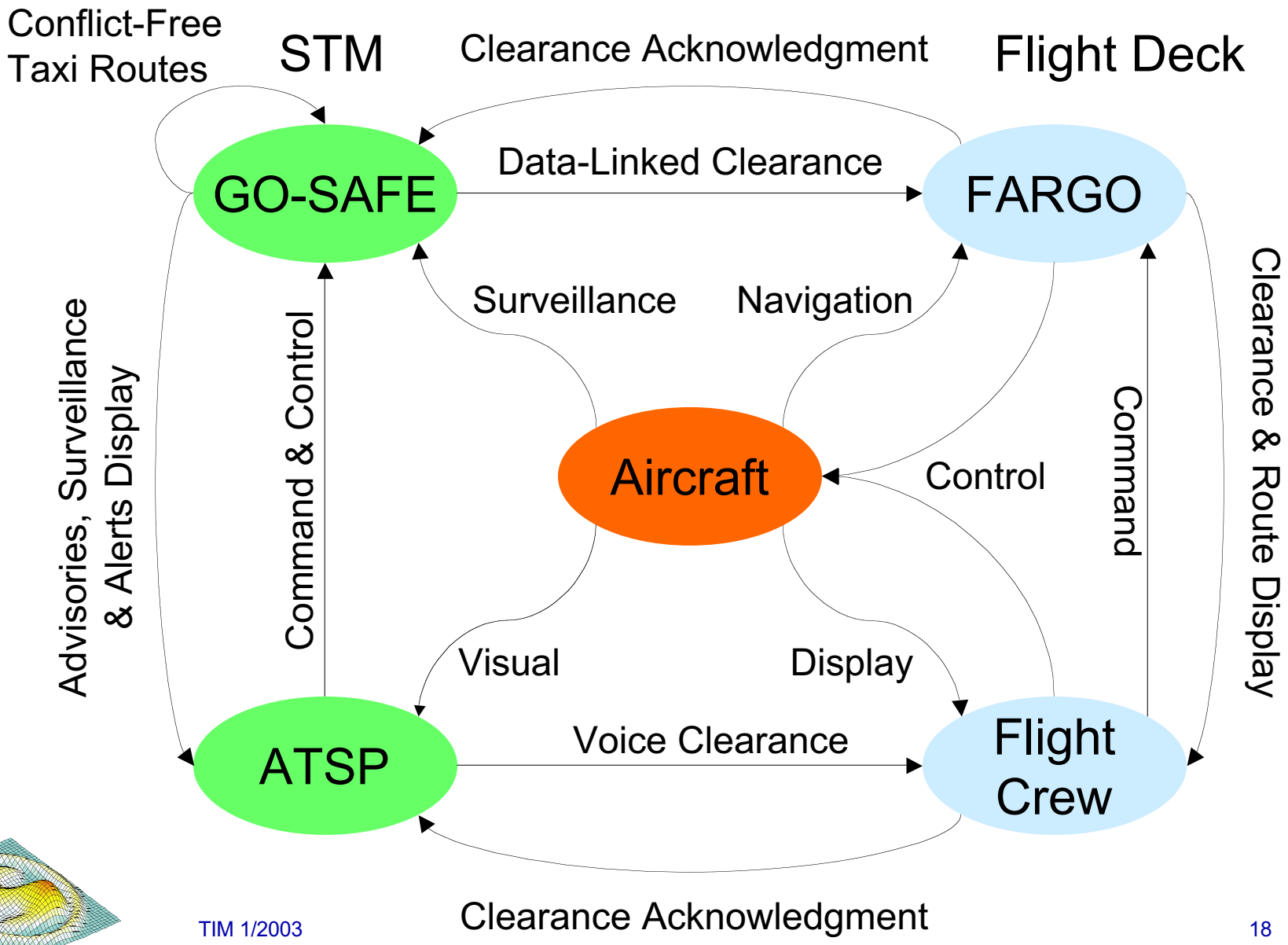
- Traditional flight director with speed bug is unsuitable.
- Pace-vehicle concept allows separation to increase with speed.
- Special consideration needs to be given to
  - Acceleration/deceleration
  - Stop/go events
- Suitable for HUD implementation: integration with T-NASA

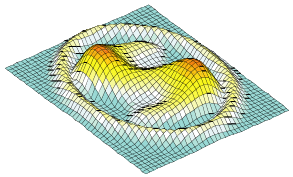




T-NASA Displays

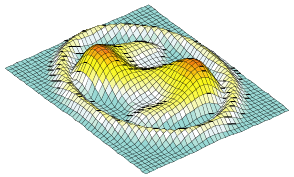
Integrated Operation of SOAR Systems





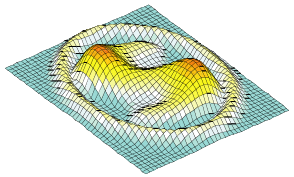
Operational Implications of SOAR Concept

- Complex taxi routes with time constraints ⇒ data-link clearances preferred over voice communcation
- Tower controller
  - Cannot expect immediate acknowledgment
  - Will likely use pre-clearances
- Flight crew
  - Cockpit crew may be distracted from flight control
    - Reading out clearances for agreement between crew members
    - Understanding details of time-based routes
    - Responding via console input
  - Route information can be more easily entered into FMS.
- Use of data-link clearances with encoded taxi routes may change hand-off procedure between local controller and ground controller.



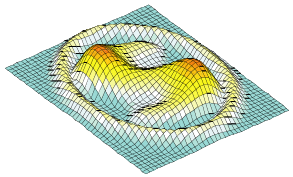
System Performance

- Common Performance Factors
  - Achievable landing and departure rates
  - Surface traffic efficiency in terms of taxi delays
  - Workload
  - Safety
- GO-SAFE
  - Scheduler effectiveness
  - Taxi routes: efficient and conflict free
  - Conformance monitor: warning signs of separation violations
  - Controller-interface effectiveness
- FARGO
  - Taxi-control effectiveness
  - Pilot-interface effectiveness
  - Conflict detection using ADS-B and TIS-B



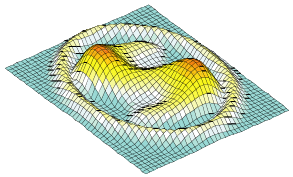
Performance Evaluation

- Field Tests: Ultimate operational evaluations
- High-Fidelity Simulations
  - GO-SAFE, PAS or GO-Sim, Aircraft Simulation + FARGO
  - Potentially human in the loop
  - Suitable for evaluation of system and human performance
- Mid-Fidelity Simulations
  - GO-SAFE to schedule and sequence flights, with taxi-route generation to predict timing
  - Operator latency and accuracy can be included in computation
  - Suitable for studying impact of surface traffic on arrival/departure traffics, interface with TRACON traffic
- Low-Fidelity Simulations
  - Empirical formulation of runway capacity for arrival and departure traffics
  - Suitable for assessing impact on system-wide concepts



Human Performance

- **Human-Factors Analyses**
  - **Human-factors experts critiquing individual design features and operational procedures**
- **Human-in-the-Loop Simulations**
  - **Controllers evaluating GO-SAFE and pilots evaluating FARGO**
  - **Pseudo-pilots operating PAS or GO-Sim to increase traffic realism**
- **Computer Simulations**
  - **Human behaviors too complex to be adequately modeled in computer simulations**
  - **Possible to identify required human operator actions in accordance with operational procedures**
  - **Actions modeled in simulation and data collected**
  - **Post-simulation analyses to include time and effort considerations in performing required actions, to assess human performance in executing procedures**



Concept Development and Technology Roadmap